PROBABILISTIC METHODOLOGY AND COMPUTER PROGRAMS FOR ASSESSMENT OF UNCONVENTIONAL OIL AND GAS RESOURCES

by Robert A. Crovelli and Richard H. Balay, U.S. Geological Survey, Denver, CO

INTRODUCTION

A geostochastic system called UNCLE (unconventional energy) was developed for the assessment of unconventional oil and gas resources. The unconventional resources that were assessed with this system for the 1995 National Assessment are of two types: (1) continuous-type accumulations, including "tight gas sands," gas-bearing shales, and autosourced oil reservoirs, and (2) coal-bed gas resources. UNCLE is an appraisal system for petroleum play analysis that uses a geologic probability model and an analytic probabilistic methodology.

In play analysis, geologic plays are defined within a petroleum assessment area, and the individual plays are analyzed. The individual play estimates of oil and gas are aggregated, respectively, to estimate the petroleum potential of the entire assessment area. Therefore, UNCLE is comprised of two separate probabilistic methodologies: one for play analysis and another for play aggregation.

The geologic model for a play consisting of a continuous-type accumulation was formulated by James W. Schmoker (U.S. Geological Survey), a geophysicist. The geologic model for a play consisting of coal-bed gas resources was formulated by Dudley D. Rice (U.S. Geological Survey), a geologist. In both of these, the number and size of production volumes of oil and gas resources are modeled.

The probabilistic methodologies that were developed to solve the play analysis model and the play aggregation problem are analytic methodologies derived from probability theory as opposed to Monte Carlo simulation. Resource estimates of potential reserve additions of unconventional oil and gas resources are calculated and expressed in terms of probability distributions.

Many steps are necessary to be able to go from the geologic probability model to the resource estimates. The complete quantitative procedure requires the following steps:

1. The geologic probability model defines an extremely complex probability problem.
2. The probability problem is characterized by a data form.
3. The data form is solved by developing a probabilistic methodology.

4. The probabilistic methodology is based on analytic probability theory.
5. The analytic probability theory is used to derive numerous mathematical equations.
6. The mathematical equations are the basis for designing computer algorithms.
7. The computer algorithms are needed to write large, complicated computer programs.
8. The computer programs are run to perform the data processing.
9. The data processing generates the resource estimates.
10. The resource estimates are produced in the form of tables or graphs.

This report is an explanation of the probabilistic methodology and computer programs developed to go from the geologic probability model to the petroleum resource estimates. The probabilistic methodology was developed by Robert A. Crovelli (U.S. Geological Survey), a mathematical statistician, and the computer programs were written by Richard H. Balay (Metropolitan State College of Denver), a computer scientist.

GEOLOGIC PROBABILITY MODEL

A geologic model for the potential reserve additions in an unconventional petroleum play involves uncertainty because of the incomplete or fragmentary geologic information generally available. The geologic probability model defines an extremely complex probability problem. The basic information required by the geologic probability model is put on a data form. The data form is filled out by the geologist who is assessing the play. (See figure 4.)

The geologic probability model for continuous-type and coal-bed gas plays consists of the following geologic and probabilistic descriptions and assumptions. (See separate chapters by Schmoker and by Rice for more detailed geologic discussion):

1. The play type is either oil or gas.

2. The play probability is the probability that necessary geologic conditions exist such that the total of the untested cells of a play are capable of producing at least a specified minimum quantity of resources; that is, the play is “favorable.”

3. The number of untested cells in the play is a discrete random variable that is characterized by three estimated values: median value, minimum value, and maximum value, which are also the fractiles F_{50}, F_{100}, and F_0, respectively, where,

for example, F_{50} denotes the value where the probability of exceeding it is 0.50. Four more fractiles F_{95}, F_{75}, F_{25}, and F_5 are calculated assuming a constructed probability distribution that is bell-shaped symmetric if F_{50} is equal to the midpoint of F_{100} and F_0, positively skewed if F_{50} is to the left of the midpoint, and negatively skewed if F_{50} is to the right of the midpoint. A second case of a uniform (or rectangular) distribution requires only estimates of the minimum value (F_{100}) and the maximum value (F_0).

4. The success ratio is the fraction of untested cells expected to be productive.

5. The estimated ultimate recovery (EUR) represents the production from untested cells expected to be productive. The EUR is a continuous random variable that is characterized by three estimated values: median value (F_{50}), minimum value (F_{100}), and maximum value (F_0); or by seven estimated fractiles: F_{100}, F_{95}, F_{75}, F_{50}, F_{25}, F_5, and F_0. In the less common case of only three given fractiles, the four remaining fractiles are calculated assuming a lognormal distribution.

6. If an oil play, the expected ratio of total gas to oil (GOR) is estimated.

7. If a gas play, the expected ratio of oil and natural gas liquids to total gas is estimated.

8. The depth of the untested cells is a continuous random variable that is characterized by three estimated values: median value, minimum value, and maximum value. The depth is not used in any of the resource calculations, but is available for economic analyses.

9. A subplay model provides an option to estimate resources in a fraction of the play from estimates of the entire play.

Probability judgments concerning the play parameters and random variables are made by experts familiar with the geology of the area of interest. The experts review all available data relevant to the appraisal, identify the major plays within the assessment area (for example, basin or province), and then assess each identified play. All the geologic data required by this model for a play are entered on an oil and gas appraisal data form. Information from the data form is entered into computer data files as the input for a computer program based upon an analytic method.

PROBABILISTIC METHODOLOGY

PLAY ANALYSIS--UNCLE

The analytic method of play analysis (UNCLE) was developed by the application of laws of expectation and variance in conditional probability theory. UNCLE systematically tracks through the geologic probability model, computes all of the means and variances of the appropriate random variables, and calculates all of the probabilities of occurrence. In arriving at probability fractiles, the lognormal distribution is used as a model for the play resource distribution (Crovelli, 1984). Oil, nonassociated gas, associated-dissolved gas, total gas, and liquids in nonassociated gas are possible resources assessed depending upon whether the type of play is oil or gas. A simplified flowchart for the method is presented in figure 1.

The basic steps of the analytic method of play analysis (UNCLE) for a given play are

1. Note the play type: oil or gas. For illustrative purposes, suppose the play type is oil.
2. Compute the mean and variance of the estimated ultimate recovery (EUR) of oil using the estimated seven fractiles and assuming a uniform distribution between fractiles; that is, a piecewise uniform probability density function.
3. Compute the mean and variance of the number of untested cells from the estimated seven fractiles, assuming a uniform distribution between fractiles.
4. Compute the mean and variance of the number of productive, untested cells by applying the success ratio of oil to the mean and variance of the number of untested cells.
5. Compute the mean and variance of the conditional (A) play potential for oil--the quantity of oil in the play, given the play is favorable. These values are determined from the probability theory of the expectation and variance of a random number (number of productive, untested cells) of random variables (estimated ultimate recovery).
6. Compute the conditional play probability of oil--the probability that a favorable play has at least one productive, untested cell. This probability is a function of the success ratio of oil and the number of untested cells distribution.
7. Compute the mean and variance of the conditional (B) play potential for oil--the quantity of oil in the play, given the play is favorable and there is at least one

productive, untested cell within the play. These values are determined by applying the conditional play probability of oil to the mean and variance of the conditional (A) play potential for oil.

8. Compute the unconditional play probability of oil--the probability that the play has at least one productive, untested cell. This probability is the product of the conditional play probability of oil and the play probability.
9. Compute the mean and variance of the unconditional play potential for oil--the quantity of oil in the play. These values are determined by applying the unconditional play probability of oil to the mean and variance of the conditional (B) play potential for oil.
10. Model the probability distribution of the conditional (B) play potential for oil by using the lognormal distribution with mean and variance from step 7. Calculate various lognormal fractiles.
11. Compute various fractiles of the conditional (A) play potential for oil by a transformation to appropriate lognormal fractiles of the conditional (B) play potential for oil using the conditional play probability of oil.
12. Compute various fractiles of the unconditional play potential for oil by a transformation to appropriate lognormal fractiles of the conditional (B) play potential for oil using the unconditional play probability of oil.
13. Process associated-dissolved gas (coproduct of an oil play) as an additional resource to be assessed. Repeat steps 2 through 12, substituting associated-dissolved gas for oil, with two basic modifications as follows. The estimated ultimate recovery (EUR) of oil is multiplied by the gas-oil ratio. The success ratio of associated-dissolved gas is the same as the success ratio of oil.
14. Suppose nonassociated gas is the resource to be assessed, that is, the play type is gas. Repeat steps 2 through 12, substituting nonassociated gas for oil and using the estimated ultimate recovery (EUR) of nonassociated gas and the success ratio of nonassociated gas.
15. Process liquids in nonassociated gas (coproduct of a gas play) as an additional resource to be assessed. Repeat steps 2 through 12 substituting liquids in nonassociated gas for oil, with two basic modifications as follows. The estimated ultimate recovery (EUR) of nonassociated gas is multiplied by the expected ratio of

liquids to nonassociated gas. The success ratio of liquids in nonassociated gas is the same as the success ratio of nonassociated gas, or zero, if the liquids ratio is zero.

A system called UNCLE-S was also developed for combining separate scenarios of the geologic model for an individual play. A geologic scenario is the basis of a completed data form for a play. For example, the two scenarios with cell sizes of 80 and 160 acres would result in two completed data forms for the same play. The scenario probability is the probability assigned to a geologic scenario of a completed data form for a play. The sum of the scenario probabilities for a play is equal to one. UNCLE-S is comprised of the probabilistic methodology for combining the resource estimates resulting from two or more completed data forms of geologic scenarios for a play.

PLAY AGGREGATION--UNCLE-AG

A separate probabilistic methodology was developed to estimate the aggregation of a set of plays (UNCLE-AG). The resource estimates of the individual plays from play analysis using the UNCLE program are aggregated using an analytic probability method. Oil, nonassociated gas, associated-dissolved gas, total gas, and liquids in nonassociated gas resources are each aggregated in turn. UNCLE-AG is also able to aggregate a set of plays under a dependency assumption. A simplified flowchart of play aggregation is presented in figure 2.

The basic steps of the analytic method of play aggregation are

1. Select plays to aggregate.

2. Process oil as the first resource to be aggregated.

3. Compute the mean, variance, and fractiles of the unconditional aggregate potential for oil in the polar case of complete independence--the quantity of oil in the assessment area of the aggregated plays under independence.

    (a) Determine the mean and variance by adding all the individual play means and variances of the unconditional play potential for oil, respectively.

    (b) Calculate the unconditional aggregate probability of oil--the probability that the assessment area has at least one play with oil--from the individual unconditional play probabilities of oil under the assumption of independence.

(c) Compute the mean and variance of the conditional aggregate potential for oil--the quantity of oil in the assessment area, given the assessment area has at least one play with oil. These are determined by applying the unconditional aggregate probability of oil to the mean and variance of the unconditional aggregate potential for oil.

(d) Model the probability distribution of the conditional aggregate potential for oil by using the lognormal distribution with mean and variance from (3c).

(e) Compute various fractiles of the unconditional aggregate potential for oil by a transformation to appropriate lognormal fractiles of the conditional aggregate potential for oil using the unconditional aggregate probability for oil.

4. Compute the mean, variance, and fractiles of the unconditional aggregate potential for oil in the polar case of perfect positive correlation--the quantity of oil in the assessment area of the aggregated plays under perfect correlation.

   (a) Determine the mean and standard deviation by adding all the individual play means and standard deviations of the unconditional play potential for oil, respectively.

   (b) Calculate the unconditional aggregate probability of oil--the probability that the assessment area has at least one play with oil--from the individual unconditional play probabilities of oil under the assumption of perfect positive correlation.

   (c) Compute various fractiles of the unconditional aggregate potential for oil by adding all the individual play fractiles of the unconditional play potential for oil, respectively.

5. Compute the mean, variance, and fractiles of the unconditional aggregate potential for oil in the case of interpolation between the polar case of complete independence ($d = 0$) and the polar case of perfect positive correlation ($d = 1$)--the quantity of oil in the assessment area of the aggregated plays under a degree of dependency, d ($0 \leq d \leq 1$). Interpolate the mean, standard deviation, fractiles, and unconditional aggregate probability of oil between the two polar cases of steps 3 and 4.

6. Compute the mean, variance, and fractiles of the conditional aggregate potential for oil in the case of interpolation--the quantity of oil in the assessment area, given the assessment area has at least one play with oil.

(a) Determine the mean and variance of the conditional aggregate potential for oil by applying the interpolated unconditional aggregate probability of oil to the interpolated mean and variance of the unconditional aggregate potential for oil.

(b) Model the probability distribution of the conditional aggregate potential for oil by using the lognormal distribution with mean and variance from (6a). Calculate various lognormal fractiles.

7. Process nonassociated gas as the second resource to be aggregated. Repeat steps 3 through 6 using play-analysis estimates of nonassociated gas--namely, the individual play means, variances, and fractiles of the unconditional play potential for nonassociated gas, as well as the individual unconditional play probabilities of nonassociated gas.

8. Process associated-dissolved gas (coproduct of an oil play) as the third resource to be aggregated. Repeat steps 3 through 6 using play-analysis estimates of associated-dissolved gas--namely, the individual play means, variances, and fractiles of the unconditional play potential for associated-dissolved gas, as well as the individual unconditional play probabilities of associated-dissolved gas.

9. Process total gas as the fourth resource to be aggregated. Repeat steps 3 through 6 using play-analysis estimates of total gas--namely, the individual play means, variances, and fractiles of the unconditional play potential for total gas, as well as the individual unconditional play probabilities of total gas.

10. Process liquids in nonassociated gas (coproduct of a gas play) as the fifth resource to be aggregated. Repeat steps 3 through 6 using play-analysis estimates of liquids in nonassociated gas--namely, the individual play means, variances, and fractiles of the unconditional play potential for liquids in nonassociated gas, as well as the individual unconditional play probabilities of liquids in nonassociated gas.

RELATIONSHIP BETWEEN UNCLE AND UNCLE-AG

UNCLE-AG is related to UNCLE as shown in figure 3. UNCLE generates not only a file of resource estimates for an individual play but also a second file of results that consists of the unconditional play probability, cutoff, mean, standard deviation, and fractiles of the unconditional play potential for each of the five resources. The second file is needed for an aggregation of plays and forms an input file for UNCLE-AG. Therefore, after UNCLE is run on each play in a set of plays, any subset of plays can be aggregated by running UNCLE-AG on the corresponding subset of aggregation input files. UNCLE-AG generates not only a file of resource estimates for an aggregation of plays but also a second file of results needed for an aggregation of aggregations, which forms yet another input file for UNCLE-AG. Hence, after UNCLE-AG is run on each aggregation in a set of aggregations, any subset of aggregations can be immediately aggregated. Compared to the simulation method, the application of UNCLE-AG can result in tremendous savings of time and cost, especially when analyzing a large number of plays in nested aggregations.

EXAMPLES

An example of a completed data form for a continuous-type accumulation play by James W. Schmoker is given in figure 4. The play is called the Intermediate Bakken in the Williston Basin. Figure 5a shows the summary of the input for the Intermediate Bakken play printed by UNCLE, and figure 5b shows the output of resource estimates. Two other Bakken plays in the Williston Basin were also assessed using the UNCLE system, namely, Outlying Bakken and Fairway Bakken. Figure 6a shows the summary of the input for the set of three Bakken plays for aggregation printed by UNCLE-AG, and figure 6b shows the output of aggregate estimates for a dependency of one ($d = 1$).

COMPUTER PROGRAMS

THE UNCLE COMPUTER SYSTEM

The system used to run UNCLE should include the following:

Hardware

IBM PC compatible computer

MS-DOS 3.1 operating system or later, or equivalent PC-DOS

monochrome or color monitor

two diskette drives, or one diskette and a hard disk

512 Kbyte memory

printer able to print 132 characters on a line

UNCLE does not require a math coprocessor, but it uses the coprocessor if one is installed in the computer, with a noticeable improvement in speed. The program does not require a graphics adapter.

Although UNCLE and UNCLE-AG are not designed specifically for the Microsoft Windows™ environment, they do run under Windows version 3.x as DOS applications either full screen or in a window. Full screen operation is recommended. The mouse cannot be used with UNCLE or UNCLE-AG.

Software

The program files containing the UNCLE software system are

UNCLE.EXE	The main system program
UNCLE-S.EXE	The scenario combiner program
UNCLE-AG.EXE	The aggregation program

Uncle operation

UNCLE handles either oil or gas plays from user-supplied data in English units, metric weight units, or metric volume units. It accepts keyboard input of parameters through a series of three display screens. Each screen contains blocks for entry of a group of parameters. When data entry is complete, the parameters are stored on a file in the user's directory.

<u>Screen #1</u>

Play name

Province name

Province number

Evaluator's name

Assessment date

<u>Screen #2</u>

Play probability

Success ratio

Gas/oil ratio

Expected liquids/gas ratio

Estimated percent of resource in subplay

Cutoffs for EUR (estimated ultimate recovery) for (a) oil

(b) nonassociated gas

Screen #3

Fractiles for oil EUR (F100, F95, F75, F50, F25, F5, F0) [see Note 1]

Fractiles for gas EUR (F100, F95, F75, F50, F25, F5, F0)

Fractiles for oil depth (F100, F50, F0) [see Note 2]

Fractiles for gas depth (F100, F50, F0)

Fractiles for number of untested cells (F100, F95, F75, F50, F25, F5, F0) [see Note 1]

Note 1: Fractiles for EUR and number of untested cells can be specified either as a full set of 7 fractiles, or as a subset consisting of minimum, median, and maximum (F100, F50, and F0). Further, fractiles for number of untested cells can be specified as a subset consisting of only minimum (F100) and maximum (F0). If only a subset is specified, UNCLE computes the missing fractiles and includes them on the program's output.

Note 2: The fractiles for depth are provided as a record, for documentation purposes and for possible use in economic analyses. Depth data are not used in computing the assessment. UNCLE expands the sets of three depth fractiles into full sets of seven fractiles by computing the missing fractiles and includes them on the program's output.

UNCLE monitors the parameters for correctness as they are entered, and issues error messages for invalid data.

PROCESSING THE PLAY

The UNCLE assessment module reads the input data file, estimates resources, and produces two output files: a listing that summarizes the input data and displays an estimate of resources in the play; and a file of parameters to be fed into UNCLE-AG (see below) for aggregating estimates of several plays after they are processed by UNCLE.

UNCLE takes from 5 seconds to 30 seconds to complete the assessment, depending on the content of the data file and the speed of the computer. It traps certain numeric errors, such as overflow or division by zero, and issues corresponding error messages.

UNCLE-AG OPERATION

UNCLE-AG aggregates the resource assessments of two or more plays from previous runs of UNCLE.

UNCLE-AG accepts keyboard input of parameters through a series of three display screens. Each screen contains blocks for entry of a group of parameters. When data entry is complete, the parameters are stored on a control file in the user's directory.

Screen #1

The first data entry screen contains names for the project and for the current aggregation. These entries are for identification, and they are reproduced on the output page. Another input on screen #1 is for entry of the inter-component dependency; it must be given as a real number in the range 0 to 1 (0 means completely independent; 1 means perfectly positively correlated).

Other screens

The screens following screen #1 contain blocks for specifying the names of up to 992 component files that will participate in the aggregation. These are files generated through previous runs of UNCLE for individual plays or of UNCLE-AG for earlier aggregations. UNCLE-AG monitors the files entered on these screens, and advises if there are errors. Errors occur if a file does not exist, if it is not a legitimate aggregation file, if its units of measure are inconsistent with other files in the list, or if the data in the file are somehow corrupted.

AGGREGATING THE PLAYS

UNCLE-AG reads the aggregation control file, aggregates resources, and produces two output files: a listing that summarizes the input data and displays an estimate of resources in the aggregation, and another file of parameters that can then participate in a higher level aggregation. UNCLE-AG may encounter computational problems with certain aggregation data files having unusually small unconditional play probabilities, due to a complex interaction between these probabilities and several other parameters of the aggregation. If this happens, UNCLE-AG outputs an error message.

PRINTING THE OUTPUT

When UNCLE or UNCLE-AG is finished, it prints (at user's option) from 0 to 9 copies of the output summary file, if a printer is connected to the PC.

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FIGURE CAPTIONS

Figure 1. Flowchart for analytic method of play analysis (UNCLE).

Figure 2. Flowchart for analytic method of play aggregation (UNCLE-AG).

Figure 3. Relationship between UNCLE and UNCLE-AG.

Figure 4. An example of a completed data form for a continuous-type accumulation play.

Figure 5a. Input summary of geologic data for the Intermediate Bakken play printed by UNCLE.

Figure 5b. Output summary of resource estimates for the Intermediate Bakken play computed by UNCLE.

Figure 6a. Input summary of resource estimates for three Bakken plays printed by UNCLE-AG. U.P.P., means unconditional play probability.

Figure 6b. Output summary of aggregate estimates for three Bakken plays computed by UNCLE-AG.

Figure 4. Data form for assessment of continuous-type accumulations. As an example, form is completed using Intermediate play of the Mississippian and Devonian Bakken Formation, Williston basin (Figure 6).

1995 NATIONAL ASSESSMENT

DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: J.W. Schmoker Province Name, No.: Williston basin, 31

Date: 8/2/94 Play Name, No.: Bakken Intermediate, 3111

(codes in parenthesis, such as III B, refer to Appendix A)

Play type: _ **Oil** or _ **Gas** (I C) _ **Confirmed** or _ **Hypothetical** (I D)

Geologic scenario (I E): **one geologic model; Crovelli distribution for number of untested cells.**

Play probability (0-1.0) (II A): __1.0__ Stop here if play probability does not exceed 0.10 (II B).

Cells (III):**Cell size** (III A1): __640__ **acres;** __1.0__ **mi^2 (acres/640)**

Area of play (III A2): __8,185__ **mi^2 Total no. of cells** (III A3): __8,185__

No. of productive cells (III B): __76__ **No. of nonproductive cells** (III C): __303__

No. of untested cells (III D): __7,806__ **50th fractile**

Minimum possible number of untested cells (III E1): __976__ **100th fractile**

Maximum possible number of untested cells (III E2): __11,709__ **0th fractile**

Success ratio (0-1.0) (IV): __0.20__

EUR probability distribution (V)*:

	Minimum			Median			Maximum
Fractile:	**100th**	**(95th)**	**(75th)**	**50th**	**(25th)**	**(5th)**	**0th**
EUR (BO or MMCF)	0	(300)	(4,800)	18,000	(59,000)	(139,000)	450,000

Data to assess co-products (VI):

_ **Oil play - expected GOR**: __800__ **CF/BO**

or_ Gas play - expected liquids/gas ratio: _____ **BO/MMCF**

*100th, 50th, 0th fractiles are required. Other fractiles should be supplied if sufficient data are available.

Selected ancillary data (VII):

Depth (ft) of untested cells (VII A): **median__10,500__; minimum__7,500__; maximum 11,100**

Fraction (0-1.0) of untested cells that will bedeeper shallower

tested by wells originally targeted for (VII B): **the play_0.8_; horizon_0.2_; horizon 0**

API gravity of liquids (VII C): **_41_ degrees**

Fraction (0-1.0) of play with "tight" FERC designation (VII D): **_0**

Fraction (0-1.0) of new wells that will be stimulated (VII E): **_0.1**

Figure 5a.   Input summary of geologic data for the Intermediate Bakker

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I N P U T   S U M M A R Y

Play Name	Province Name
Intermediate Bakken Continuous, 3111	Williston Basin

Play Type	Play Probability	Success Ratio	Scenario
Oil	1.000	0.200	

Geologic Variables	F100	F95	F75	F5(
Oil EUR* (10^6 BBL)	0.00000	0.00030	0.00480	0.01ε
NA Gas EUR* (10^9 CF)	0.00000	(0.00000)	(0.00000)	0.00(
Oil Cells Depth (10^3 Ft)	7.50000	(8.50000)	(9.75000)	10.5(
Gas Cells Depth (10^3 Ft)	0.00000	(0.00000)	(0.00000)	0.00(
Number of Untested Cells	976	(3253)	(6098)	7ε

* EUR = Estimated Ultimate Recovery

Gas-Oil Ratio CF/BBL	Expected Liquids/Gas Ratio BBL/10^6 CF	Estimated % of resourc
800.0000	0.0000	100.0000

G E O L O G I C   V A R I A B L E S and P R O B A B I L I T I E S   (

	Mean	Std. Dev.
Cond. # Cells	7396.87	2297.65
# Cells	7396.87	2297.65
Oil Cell Depth	10.1162	0.80938
Gas Cell Depth	0.00000	0.00000

	Oil	NA
Prob. Untested Cell has	0.2000	0.
Cond. Play Prob.	1.0000	0.
Uncond. Play Prob.	1.0000	0.
Prob. Exceed Cutoff	1.0000	0.
Play Potential Cutoffs	0.0000	0.

Figure 5b. Output summary of resource estimates for the Intermediate

UNCONVENTIONAL RESOURCES for Intermediate Bakken Continuous, 3111 C:\UN

	Mean	Std. Dev.	F95	F75	--
OIL (10^6 BBL)					
No. Prod. Untested Cells	1479.38	460.817	.....	.....	.
Est. Ultimate Recovery	0.04752	0.07065	.....	.....	.
Cond. Play Potential	70.2962	22.0649	40.5071	54.5421	67
Uncond. Play Potential	70.2962	22.0649	40.5071	54.5421	67
NONASSOCIATED GAS (10^9 CF)					
No. Prod. Untested Cells	0.00000	0.00000	0	0	
Est. Ultimate Recovery	0.00000	0.00000	0.00000	0.00000	0.
Cond. Play Potential	0.00000	0.00000	0.00000	0.00000	0.
Uncond. Play Potential	0.00000	0.00000	0.00000	0.00000	0.
ASSOCIATED-DISSOLVED GAS (10^9 CF)					
No. Prod. Untested Cells	1479.38	460.817	.....	.....	.
Est. Ultimate Recovery	0.03801	0.05652	.....	.....	.
Cond. Play Potential	56.2370	17.6519	32.4056	43.6337	53
Uncond. Play Potential	56.2370	17.6519	32.4056	43.6337	53
TOTAL GAS (10^9 CF)					
No. Prod. Untested Cells	1479.38	460.817	.....	.....	.
Est. Ultimate Recovery	0.03801	0.05652	.....	.....	.
Cond. Play Potential	56.2370	17.6519	32.4056	43.6337	53
Uncond. Play Potential	56.2370	17.6519	32.4056	43.6337	53
LIQUIDS in NONASSOC. GAS (10^6 BBL)					
No. Prod. Untested Cells	0.00000	0.00000	0	0	
Est. Ultimate Recovery	0.00000	0.00000	0.00000	0.00000	0.
Cond. Play Potential	0.00000	0.00000	0.00000	0.00000	0.
Uncond. Play Potential	0.00000	0.00000	0.00000	0.00000	0.

Figure 6a.   Input summary of resource estimates for three Bakken plays
probability.

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I N P U T   S U M M A R Y   Project : Continuous-Type Accumulation

Component	Resource	U.P.P.	Cutoff	Mean	S.D.
Fairway Bakken Conti- BBL	Oil	1.00000	0.00000	72.7169	25.0710
nuous, 3110	NA-Gas	0.00000	0.00000	0.00000	0.00000
	AD-Gas	1.00000	0.00000	65.4452	22.5639
(3110.agg)	Gas	1.00000	0.00000	65.4452	22.5639
	NA-Gas-Liq	0.00000	0.00000	0.00000	0.00000
BBL					
Intermediate Bakken - BBL	Oil	1.00000	0.00000	70.2962	22.0648
Continuous, 3111	NA-Gas	0.00000	0.00000	0.00000	0.00000
	AD-Gas	1.00000	0.00000	56.2369	17.6518
(3111.agg)	Gas	1.00000	0.00000	56.2369	17.6518
	NA-Gas-Liq	0.00000	0.00000	0.00000	0.00000
BBL					
Outlying Bakken Cont- BBL	Oil	0.70000	0.00000	8.15790	6.15905
inuous, 3112	NA-Gas	0.00000	0.00000	0.00000	0.00000
	AD-Gas	0.70000	0.00000	6.52632	4.92724
(3112.agg)	Gas	0.70000	0.00000	6.52632	4.92724
	NA-Gas-Liq	0.00000	0.00000	0.00000	0.00000
BBL					
All 3 Bakken BBL	Oil	1.00000	0.00000	151.171	53.2949
	NA-Gas	0.00000	0.00000	0.00000	0.00000
	AD-Gas	1.00000	0.00000	128.208	45.1431
	Gas	1.00000	0.00000	128.208	45.1431
	NA-Gas-Liq	0.00000	0.00000	0.00000	0.00000
BBL					

Figure 6b.   Output summary of aggregate estimates for three Bakken pla

E S T I M A T E D   R E S O U R C E S   for All 3 Bakken C:\UNCONV\CONTI

	Mean	Std Dev	F95	F75	F5
Oil (10^9 BBL)					
Cond Aggregate Potential	0.151171	0.053295	0.080118	0.109379	0.14
Uncond Aggregate Potential	0.151171	0.053295	0.080118	0.109379	0.14
Nonassociated Gas (10^12 CF)					
Cond Aggregate Potential	0.000000	0.000000	0.000000	0.000000	0.00
Uncond Aggregate Potential	0.000000	0.000000	0.000000	0.000000	0.00
Associated-Dissolved Gas (10^12 CF)					
Cond Aggregate Potential	0.128209	0.045143	0.068056	0.092987	0.12
Uncond Aggregate Potential	0.128209	0.045143	0.068056	0.092987	0.12
Total Gas (10^12 CF)					
Cond Aggregate Potential	0.128209	0.045143	0.068056	0.092987	0.12
Uncond Aggregate Potential	0.128209	0.045143	0.068056	0.092987	0.12
Nonassoc. Gas Liquids (10^9 BBL)					
Cond Aggregate Potential	0.000000	0.000000	0.000000	0.000000	0.00
Uncond Aggregate Potential	0.000000	0.000000	0.000000	0.000000	0.00